Modeling and Control of Nonlinear Hybrid Dynamical Systems (NHDS) with Applications to Process Industry

Naresh N. Nandola
Advisor: Prof. Sharad Bhartiya
Automation Lab
Tel.: 2576 4229
Email: naresh_nandola@che.iitb.ac.in

Hybrid systems are used to describe processes that involve discrete decisions in addition to continuous dynamics and have found applications in diverse areas such as manufacturing systems, automobile control, and computer disk drive control among others. Although the use of a hybrid system framework in modeling and control of chemical processes has emerged only recently, large continuous plants have always used logic controllers to implement safety features and various safety interlocks. However, current trends in the chemical process industry emphasize the need for flexible processing, which invariably necessitates a greater degree of logical decision-making along with the continuous control laws.

The aim of this work is to develop computationally efficient models, control and estimation schemes for NHDS. Optimal feedback control, such as MPC, of NHDS is challenging as it typically requires an online solution of a MINLP/MIQP within a small fraction of the sampling period. This impediment to control of NHDS can be addressed along three paths: (i) efficient representation of the NHDS, (ii) efficient algorithms for the solution of MINLP/MIQP, and (iii) enhanced computer speed. We address the first aspect by developing a novel multiple, partially linearized (MPL) model. This modeling framework is used for synthesis of a MPC control law. Although implementation of the MPC requires an online solution of an MINLP, the optimization problem resulting from use of the MPL model has a fixed structure with certain computational advantages. We address the second impediment by developing an efficient generalized outer approximation algorithm for solving such MINLPs. This algorithm exploits the structure to reduce the primal and master problems into a QP and a MILP, respectively. Moreover, the fixed structure of the MINLP enables us to derive analytical gradients for the nonlinear objective function and constraints, which further speed up the solution.

The computational advantage of the proposed MPL model based control scheme and MINLP algorithm are demonstrated on two different applications, namely a three-spherical tank system and a hydraulic process plant by simulation study. Further, these results are also verified on a lab scale benchmark setup fabricated.